# MANAGEMENT OF RESPIRATORY PARALYSIS USING A "MECHANICAL COUGH" RESPIRATOR

BY

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Pulmonary disease has been the major contributing factor to deaths among patients undergoing prolonged artificial respiration. The removal of secretions which produce bronchiolar and bronchial obstruction with consequent pulmonary collapse, and favour the persistence of infection, constitutes the principal difficulty in the management of most of these cases.

Tracheotomy, which is designed to provide a more efficient airway and access to the trachea in certain patients, does not materially assist in ridding the bronchi of secretions which must migrate to the upper bronchi and trachea before they become accessible to suction through the tracheotomy tube. The inaccessibility of these secretions in the lower bronchial tree even to bronchoscopy makes it necessary to provide indirect means for their mechanical expulsion.

More rapid flow of air in the bronchi on expiration than on inspiration in conjunction with ciliary action is a physiological factor in the normal evacuation of the bronchial tree; coughing creates an expiratory blast of air capable of expelling relatively large amounts of viscid material from the lower pulmonary tract.

Barach *et al.* (1952) have shown that a useful cough may be simulated mechanically by opening a large port in the side of a tank respirator at the end of the inspiratory phase in isolated respirations when using high negative intratank pressures. This device has proved useful in the treatment of cases with chronic bronchial infection, and has been applied successfully to patients with respiratory paralysis undergoing artificial respiration in tank respirators. Cherniack *et al.* (1952) have also demonstrated physiological advantages of this effect, particularly in obstructed breathing.

It has been shown that lobular collapse is related to inadequate alveolar inflation, and in circumstances when there is some bronchial or bronchiolar obstruction in conjunction with shallow breathing lobular collapse may occur through inadequate collateral ventilation (Van Allen *et al.*, 1931). To obviate this, higher respiratory volumes have been used in routine artificial respiration.

These have been the basic considerations, in recent years, leading to three main improvements in the design of tank respirator bellows—namely, the introduction of larger bellows capable of producing a greater range of pressures and, consequently, larger respiratory volumes; the addition of an automatically actuated valve designed to open suddenly at the end of inspiration so that the air in the lungs is expelled rapidly by the sudden recoil of chest wall and lungs; and the use of a larger intratank positive-pressure phase so that the patient's chest and abdomen are compressed at each expiration.

This paper describes the modification of tank respirator bellows which enables the simulation of coughing and which produces forcible expiration automatically with each breath.

The associated principles of management of the acute respirator cases, including the use of larger respiratory volumes than usually described, and the results of treatment of patients admitted to Fairfield Hospital with poliomyelitis are also included.

The equipment described has been designed and manufactured at Fairfield Hospital, where tank respiration has been retained as the method of choice in the respiratory centre. This matter is also discussed.

### Modification of Bellows

During the past two and a half to three years modifications have been made to the tank respirator bellows to provide greater versatility in management. The bellows have been enlarged to provide a greater range of pressures and the belt drive has been replaced by a variable speed drive to enable more precise and rapid adjustment of respiratory rate.

The respirator bellows in use are of the Selby–Noble type, which are circular, with a diameter of 27 in. (68.5 cm.), have a horizontal stroke of 7 in. (18 cm.), and are capable of producing negative pressures within the tank respirator of about −25 in. (−63.5 cm.) of water.

Forcible expiration was initially produced by means of an automatically actuated valve attached to the mobile side of a Selby–Noble bellows as shown in Fig. 1. These bellows are used in conjunction with a standard tank respirator.

The valve (AV) is opened abruptly at the end of the negative pressure or inspiratory phase of each stroke so that the pressure within the system reverts suddenly to

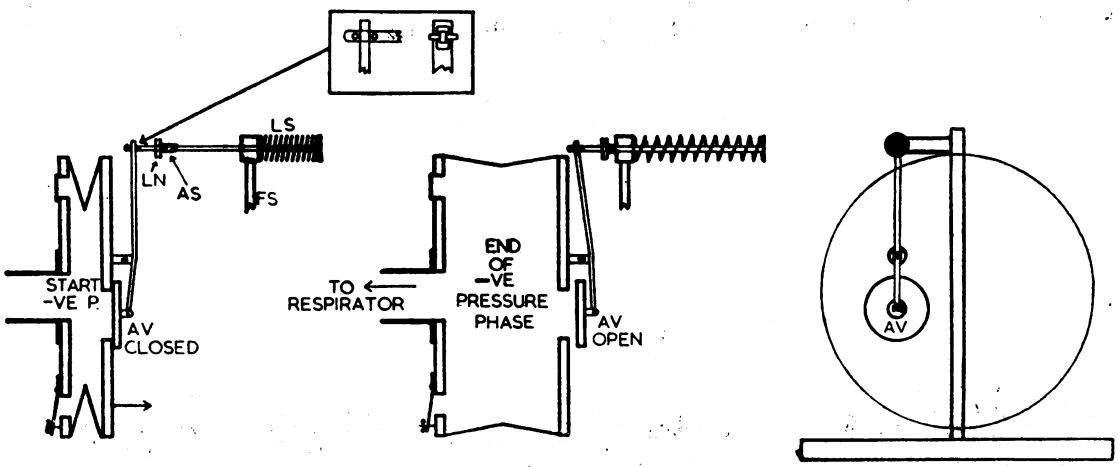


FIG. 1.—Diagrammatic representation of an expiratory valve fitted to a Selby–Noble bellows.

atmospheric pressure. This abrupt expiratory reversion of pressure allows rapid deflation of the patient's lungs by the recoil of the distended lungs and thoracic walls as in normal breathing.

The valve (AV) is opened automatically by the impact of the buffer spring (AS) against the fixed support (FS) as the rod which holds it is moved back by the mobile side of the bellows. At the same time the loading spring (LS) is placed under tension so that the valve (AV) is closed on the return stroke of the bellows prior to the positive-pressure phase, which occurs over the last half of the return (expiration) stroke. The loading spring is powerful enough to keep the valve closed against the positive pressure required. The time relations of these changes of pressure within the tank respirator are shown in Fig. 2.

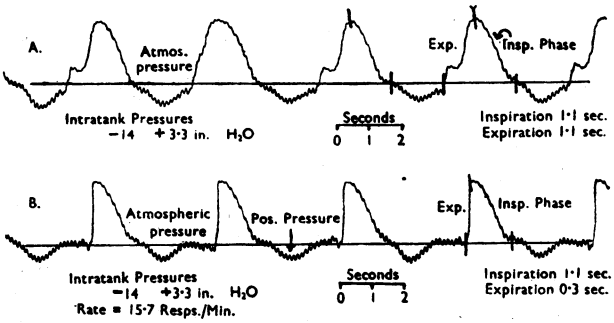


FIG. 2.—Intratank pressure curves. A, without valve in operation. B, with valve in operation.

The lock nuts (LN) provide a means of altering the point in the respiratory cycle at which the valve (AV) opens. It has been found that a setting to open the valve just before the end of the negative-pressure (inspiratory) stroke is most suitable.

The design of the valve has been simplified since it was originally introduced (see Fig. 3). It is now opened on the moving side of the bellows by means of a short lever (L)

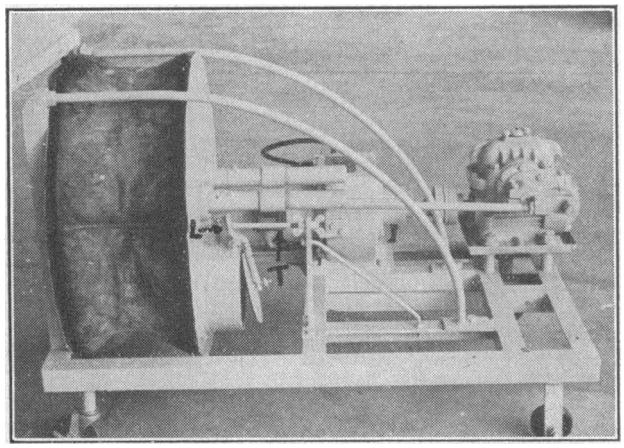

FIG. 3.—Photograph of Selby-Noble bellows showing the simplified expiratory valve.

coming into contact with a fixed trigger (T) at the end of inspiration. The valve opening is large enough to allow the intratank negative pressure to revert suddenly to atmospheric pressure as before. The positive-pressure phase is maintained by the provision of a flap which closes the valve opening internally on the return stroke of the bellows.

### Intratank Pressure Changes

The recorded changes of pressure within a tank respirator produced by bellows without an expiratory valve or cam approximate to a sine curve (see Fig. 2, A), so that the expulsion of air from the lungs in the expiratory phase is controlled by the bellows and occurs at the same rate as it is drawn in during inspiration.

Operation of the actuated valve causes intratank pressure to revert abruptly in the expiratory phase (see Fig. 2, B), so that the patient's expiration is uncontrolled by the bellows and the air in the lungs is expelled rapidly by the sudden recoil of the chest wall and the lungs. The expiratory impulse produced in this way in the bronchi varies with the negative pressure produced in the system in the inspiratory phase of the cycle. With a negative (inspiratory) pressure of −15 in. (−38 cm.) of water, reversion to atmospheric pressure in the expiratory phase takes 0.3 second instead of 1.1 seconds when the valve is not in operation (see Fig. 2). When the maximum negative intratank pressure of −25 in. (−63.5 cm.) is used the sudden recoil of the chest wall and lungs simulates an effective cough in an adult.

### Principles of Management

Changes in technique here in recent years have involved the use of larger respiratory volumes than usually reported, the routine use of the expiratory valve and intermittent cough simulation, and the application of a higher intratank positive-pressure phase to produce chest compression on each expiration.

In patients with relatively normal lungs, higher routine tank pressures with a consequent increase in respiratory volumes have been used to prevent pulmonary atelectasis by fuller inflation of the lungs, to maintain collateral ventilation, to retain chest-wall mobility, and (by utilizing the expiratory valve) to produce an expulsive effect by having a more rapid flow of bronchial air in expiration. It has been found that most acute patients are improved by respiratory volumes one and a half times greater or even more than those indicated by nomograms.

Prior to the introduction of the expulsive bellows, an expiratory impulse was produced intermittently by manually opening a port in the side of the tank at the end of inspiration for varying periods of time. This was helpful, but less effective than the valve which operates continuously.

The positive-pressure phase in each cycle is designed to expel the supplemental air, to reduce residual volume, and to evacuate $CO_2$ efficiently. It maintains a minimum resting thoracic volume and prevents the eventual occurrence of a relatively immobile distended thoracic cage which occurs with unopposed chest distension. Also, it is designed to aid venous return by compression of the abdominal wall and veins. Higher positive pressures than formerly have been used.

Negative or inspiratory tank pressures ranging from −8 to −15 in. (−20 to −38 cm.) of water balanced by a positive-pressure phase of up to +8 in. (+20 cm.) of water, varying with the size, musculature, and respiratory requirements of each patient, are employed to produce basic respiratory volumes from about 400 ml. in children to 1,400 ml. in some male adults. In recent patients positive pressures of +7 in. (+18 cm.) have been used successfully in children.

With respiratory volumes of the order described, rates of 14 to 16 a minute in adults and up to 16 or 18 a minute in children have been adequate.

When the patient is first placed in a respirator the pressures are gradually increased over half an hour to the selected basic pressures, which require repeated review. A gradual increase in pressure accompanied by an explanation to the patient whose co-operation is sought not only assists him to acclimatize but also obviates the danger, in some cases, of forcing large quantities of tracheal mucus suddenly into the larynx.

The respiratory excursion and rate are determined individually for each patient according to his size, oxygen requirements and evidence of $CO_2$ retention, his respiratory volume—which in turn depends upon the state of the lungs—the presence of bronchial and tracheal secretions, and, where possible, also the subjective requirements of the patient.

Since the "cough effect" of the bellows increases with the negative tank pressure the question of overventilation arises when a greater "cough effect" is required, but in assessing this problem the patient's need for "coughing" takes precedence. By gradually altering the respiratory volume no difficulty as a result of overventilation has been experienced.

Assessment of the patient's oxygenation by clinical observation and measurement of respiratory volume in relation to the intratank pressures and size of the patient provides an index of the state of the patient's lungs. Sudden deterioration in colour, which usually indicates an abrupt fall in respiratory volume, may be ascribed to a severe degree of airway obstruction or pulmonary collapse, indicating the necessity for mechanical "coughing." The obvious presence of tracheal mucus is treated similarly, and in the acute stage mechanical coughing is induced at half-hourly or hourly intervals in the absence of specific indications. To simulate a cough in adults, the tank negative pressure is increased to −25 in. (−63.5 cm.) of water for half a minute or so according to the requirements of the patient. Smaller negative pressures are used for children.

The measurement of $CO_2$ in expired air is also of value in determining pressures and respiratory volume. The measurement of blood pressure as an index of $CO_2$ retention is used particularly in relation to the determination of intratank positive pressure.

The ease with which artificial respiration is carried out depends largely on the state of the patient's lungs at the outset. A difficult problem is presented by patients who have developed respiratory failure or pharyngeal paralysis before coming under observation. In these patients pulmonary collapse or consolidation, with a diminution of functioning pulmonary tissue, may be present at the time of admission to hospital.

An example is provided in this series by an adult male patient who was admitted to hospital with poliomyelitis, having had pharyngeal paralysis for 36 hours, during which time the history suggested that inhalation of oral contents had occurred. On admission there was clinical evidence of pneumonia and gross restriction of respiratory volume. Cyanosis was partially relieved by tracheotomy, but artificial respiration failed to produce much improvement in oxygenation, and the patient died 36 hours later. At the post-mortem examination there was consolidation of about three-quarters of the entire pulmonary tissue, and it seemed that the pulmonary insufficiency was due more to consolidation than to respiratory paralysis.

In cases such as this it is often difficult to determine the extent of respiratory weakness when there is gross restriction of respiration as a result of pulmonary incapacity in a patient with severe poliomyelitis.

A similar situation occurs also in patients with undetected respiratory weakness (whose cough and respiratory excursion are inadequate), so that bronchial and tracheal mucus accumulates and predisposes to infection. If the consequent reduction in respiratory volume is due to an impaired airway, tracheotomy and tracheal suction in conjunction with artificial coughing usually lead to a dramatic improvement in respiratory volume at given intratank pressures. When these measures fail and the respiratory volume is relatively fixed in spite of increasing intratank pressures, indicating probable consolidation with a reduction of functional lung volume, the lowest intratank pressures producing the relatively fixed respiratory volume are selected and the respiratory rate is increased to provide an adequate minute-volume. These measures can be supplemented by the use of oxygen even under pressure.

When out of the respirator, the patients are maintained by the intermittent intratracheal positive-pressure oxygen.

Recently the rocking-bed has been used in conjunction with the tank respirator for selected patients in the acute stage to extend the zones of fully functioning pulmonary tissue.

The question of tracheotomy has been dealt with elsewhere (Forbes, 1955); it is carried out only in patients who have or are in immediate danger of developing airway obstruction, to provide an efficient airway.

If possible, sedation is avoided completely and is used only after weighing the worsening of prognosis against the likely course of a particular patient if not sedatized.

Antibiotics are used in most patients either prophylactically or for the treatment of pulmonary and urinary infections.

The management of fluid balance often adds to the difficulties of artificial respiration for some period during the acute stage. The intragastric administration of Darrow's solution and high-protein fluid in the early stages according to the patient's fluid requirements, which are usually high (Bower, 1954), is a routine measure. Intravenous infusions and calculations of electrolyte state are required in patients who develop some degree of paralytic ileus for varying but usually short periods during the acute stage.

The selection of patients for artificial respiration is based on the clinical assessment of respiratory reserve, oxygen want, and fatigue in relation to the progress of paralysis. Colour, speech, subjective reaction, rate and depth of respiration, occasionally respiratory volume (the measurement of which has not often been found to be practicable in this acute stage of the illness), pulse rate, blood pressure, and rate of change of these, are factors in assessment.

### Case Reports of the Initial Clinical Application of Expiratory Impulse Bellows

Initially the device was used successfully in two adult patients with acute spino-bulbar poliomyelitis. It has also been used in chronic respiratory cases in which the removal of tenacious bronchial secretions was a problem. Two acute cases are described below.

*Case 1.*—The first of the acute cases was that of a heavily built man aged 23, 6 ft. 2 in. (188 cm.) in height, who weighed about 200 lb. (91 kg.). Weakness of his legs became apparent on the third day of the major illness and progressed rapidly, so that he required artificial respiration at the end of the fourth day. Initially, a tank respirator fitted with the old-type bellows was used when his pharynx and trachea were relatively dry. On the sixth day tracheal mucus was impairing oxygenation of his blood, so that he was irrational and had intermittent cyanosis. At this stage the bellows providing forcible expiration were fitted to his tank respirator and the negative pressure was gradually increased to operate routinely at −16 in. (−40 cm.) and at times at −18 in. (−46 cm.) of water, and from 3 to 6 in. (7.5 to 15 cm.) of water in the positive-pressure phase at a rate of 15 strokes a minute. These pressures produced an expiratory blast of air sufficient to hasten the migration of secretion which was previously troublesome. On occasion, when a large volume of secretion collected in the vicinity of his glottis, the negative pressure was increased to over 20 in. (50 cm.) of water for a few cycles, to simulate a cough. After two days the volume of secretion subsided rapidly and his airway has remained clear since that time. It is probable that this patient was saved a tracheotomy. His respiratory volume in the respirator at pressures of −15 +5 was in the vicinity of 1,200 to 1,400 ml.

*Case 2.*—This case was that of a woman aged 31, and was more nearly bulbar in type. She developed palate and pharyngeal paralysis and, later, some weakness of arms and partial involvement of the diaphragm and intercostals. Initially, her respiratory power was just adequate, so that it was possible to nurse her in a dependent posture with intermittent postural drainage, using a Rehfuss tube for the administration of fluids, etc. Her pharynx was cleared of secretions by repeated mechanical suction. She developed bronchial infection with some further diminution of respiratory power, and on the tenth day of her major illness she suddenly became cyanosed owing to collapse of a pulmonary segment, demonstrable on *x*-ray screening. At this stage she

was placed in a tank respirator fitted with expiratory impulse bellows, without performing a tracheotomy. She was nursed in the respirator in the head-down position. The tank pressures were gradually increased to routine pressures of −14 and +5 in. (−35.5 and +12.5 cm.) of water; these were increased for short periods to −18 and +5 in. (−46 and +12.5 cm.) of water, and for isolated respirations to −20 and +5 in. (−50 and +12.5 cm.) of water to simulate coughing when it appeared necessary. Prior to the successful use of this device in the previous case, a tracheotomy would have been performed in such a patient with pharyngeal paralysis before she was placed in the respirator. Large quantities of thick tracheal mucus were aspirated from her pharynx which postural drainage methods had failed to expel, and the collapsed pulmonary lobe re-expanded.

For the last two years all acute cases, and chronic cases in which acute bronchial and tracheal infection has been a problem, have been given artificial respiration with these bellows.

### Results of Treatment—1953–6

It is universally found that the results of artificial respiration in poliomyelitis are better in children than in adults, and in females than in males, so that for purposes of comparison the recent results at Fairfield Hospital are presented in detail.

During 30 months from July, 1954, 295 patients with paralytic poliomyelitis were admitted (169 were under the age of 15 years and 126 were 15 and over); 85 had respiratory or pharyngeal paralysis, 32 of them being under 15. Thirty-nine, of whom 10 were under 15, required prolonged artificial respiration. Seventeen, 10 of them under 15, had pharyngeal paralysis without requiring artificial respiration, although, in some, respiratory muscles were involved to a certain extent as well. One male adult in this latter group died suddenly with cardiac arrest without having respiratory paralysis, and another, not in the respiratory or pharyngeal group, who had palate paralysis only, died suddenly, apparently of cardiac or medullary failure. Type 3 poliovirus was isolated from both these cases, and evidence of severe medullary damage was found at necropsy.

Of the adult group of 29 patients requiring artificial respiration, 21 were males, and 6 of them died, there being only one death amongst the eight female patients. The sex distribution was equal amongst the 10 children requiring artificial respiration, and the single death occurred in a male child (see Table I).

TABLE I.—*Patients with Acute Poliomyelitis Undergoing Artificial Respiration, 1954–6. Age and Sex Differences in Relation to Mortality*

| Age Group | Male | | Female | |
|---|---|---|---|---|
| | No. | Mortality | No. | Mortality |
| Under 15 years .. | 5 | 1 (20%) | 5 | 0 (0%) |
| 15 years and over .. | 21 | 6 (28·6%) | 8 | 1 (12·5%) |

The virus types causing these cases varied in the different epidemics. In 1954–5, when 168 paralytic cases were admitted, type 1 poliovirus predominated, while since July, 1955, all three types of virus have predominated at different times. During February, March, and April, 1956, when type 3 was the prevailing cause of the paralytic cases (type 3 50%, type 1 31%, and type 2 19% of viruses isolated), four male adults died, type 3 poliovirus being isolated from three of them. During this type 3 phase it was found that the adults with severe poliomyelitis appeared to have evidence of more severe and more generalized brain damage than at times when type 1 or type 2 poliovirus predominated.

The comparison of mortality figures for the previous year suggests that the changes in equipment and technique described have been associated with improvement in regard to mortality. Whereas in 1953–4 (12 months) 32 cases of poliomyelitis underwent artificial respiration, leading to 11 deaths (34.4%), in 1954–6 (30 months) 39 cases had artificial respiration, resulting in 8 deaths (20.5%) (see Table IV).

The presentation of mortality as a percentage of cases with respiratory and pharyngeal paralysis obviates to some extent the difficulty of assessing criteria for commencing artificial respiration which may influence the mortality figures of cases undergoing artificial respiration at different centres.

Table II shows a comparison of these mortality figures for the two periods in both adults and children. Whereas eight deaths (21.7%) occurred amongst 37 patients aged 15 and over during 1953–4, eight deaths (15.1%) (including one patient who died before requiring artificial respiration) occurred amongst 53 patients in the same age group during the 30 months 1954–6. In those under 15 the mortality of three (10%) of 30 cases in 1953–4 was reduced to one (3.1%) of 32 cases in the latter period.

TABLE II.—*Poliomyelitis Cases with Pharyngeal and Respiratory Paralysis*

| Source | 15 Years and Over | | | Under 15 Years | | |
|---|---|---|---|---|---|---|
| | No. | Requiring Artificial Respiration | Mortality | No. | Requiring Artificial Respiration | Mortality |
| Fairfield Hospital: 1953–4 (12 months) | 37 | 19 | 8 (21·7%) | 30 | 13 | 3 (10%) |
| 1954–6 (30 months) | 53 | 29 | *8 (15·1%) | 32 | 10 | 1 (3·1%) |

* Including one case with pharyngeal paralysis which required tracheotomy but not artificial respiration (see text).

In 1953–4 tracheotomy was performed in 15 cases, whilst in 1954–6 it was performed in 14.

Table III gives brief details regarding the eight patients who died whilst undergoing artificial respiration. In three of these, associated illness contributed to their deaths. One obese man aged 47 had been treated for proved coronary occlusion six weeks before the onset of severe poliomyelitis. A woman aged 25, who was eight months pregnant at the time of admission to hospital, had a concealed uterine haemorrhage, and came into labour during the acute phase of her illness whilst undergoing artificial respiration. The third of these, a man aged 29, with severe generalized poliomyelitis who had long-standing ulcerative colitis, died after satisfactory artificial respiration for four weeks, during an exacerbation of colitis. Four males, including the child, died during the acute stage of the major illness (two within 24 hours of admission) with severe generalized poliomyelitis. In the remaining case a man aged 32 was admitted with

TABLE III.—*Deaths Occurring During Artificial Respiration*

| Case | Sex | Age | Details of Death |
|---|---|---|---|
| 1 | M | 47 | Obese; previous coronary occlusion; severe generalized poliomyelitis. Died in acute stage |
| 2 | F | 25 | Eight months pregnant on admission. Parturition with concealed haemorrhage whilst undergoing artificial respiration during acute stage |
| 3 | M | 29 | Generalized poliomyelitis, associated with ulcerative colitis. Died after 4 weeks of satisfactory artificial respiration during exacerbation of ulcerative colitis |
| 4 | M | 3 | Severe generalized poliomyelitis. Died within 24 hours of admission |
| 5 | M | 25 | Severe generalized poliomyelitis. Died within 24 hours of admission after journey of over 100 miles |
| 6 | M | 36 | Severe generalized poliomyelitis. Died during acute stage |
| 7 | M | 34 | Severe generalized poliomyelitis with severe involvement of hypothalamus and cerebrum. Artificial respiration and subnormal temperature (not recordable) for 4 days before death occurred |
| 8 | M | 32 | Admitted with severe pharyngeal paralysis and severe aspiration pneumonia. Doubtful if artificial respiration was required as respiratory insufficiency probably due more to pulmonary consolidation than to respiratory weakness |

severe pharyngeal paralysis which had been present for at least 36 hours and coexisting pneumonia which was probably due to the aspiration of oral contents. In this case it was decided after necropsy that the respiratory insufficiency was probably due more to extensive pulmonary consolidation than to respiratory weakness.

## Discussion

There is still some controversy regarding the method of choice for providing prolonged artificial respiration in centres designed for that purpose; the recent European school, arguing particularly from experience during the Danish epidemic in 1952, advocates intratracheal positive-pressure methods, while the older American school, basing itself on the work of Drinker and Wilson in 1929–31, continues to improve the tank respirator.

Tank respiration has been retained as the basic method in the respiratory centre at Fairfield Hospital for the following reasons.

1. The published mortality amongst acute patients is lower with tank respiration than with intratracheal positive-pressure respiration (Affeldt, 1954; Lassen, 1954; O'Brien *et al.*, 1954; Forbes, 1955; Harries and Lawes, 1955; James, 1955) (see Table IV).

TABLE IV.—*Comparison of Cases Undergoing Artificial Respiration (Published Results)*

| Source | No. of Cases | Mortality |
|---|---|---|
| Copenhagen 1952. (1 year.) (Lassen, 1954) | *232 (I.T.P.P.) | 119 (51·3%) |
| San Francisco (Washoe, M. C.) 1952–4. (3 years.) (O'Brien *et al.*, 1954) | †51 (Tank R.) | 12 (23·5%) |
| Fairfield: | | |
| 1953–4 (1 year) | ‡32 ,, | 11 (34·4%) |
| 1954–6 (30 months) | §39 ,, | 8 (20·5%) |

* Tracheotomy in all cases. † Tracheotomy in 30 cases. ‡Tracheotomy in 15 cases. § Tracheotomy in 13 cases.

2. Tracheotomy, with the inevitable tracheobronchitis, is not necessary in more than half the patients with poliomyelitis who require artificial respiration, being essential only in patients, particularly those with pharyngeal paralysis, who have an impaired airway. It is considered that unnecessary tracheotomy in patients with respiratory paralysis worsens their prognosis.

3. The risks of tracheal damage by a cuffed tube and the dangers of circulatory changes as the result of unopposed intratracheal positive pressure (Maloney and Handford, 1954) do not arise. Furthermore, the convalescent mobilization of chronic patients which is facilitated by glossopharyngeal breathing is quicker and simpler in the absence of tracheotomy.

4. The expiratory impulse, with the possibility of cough simulation by modern bellows, has reduced respiratory complications, and the routine application of chest compression provides an easy method of evacuating $CO_2$ and restoring expiratory chest volume.

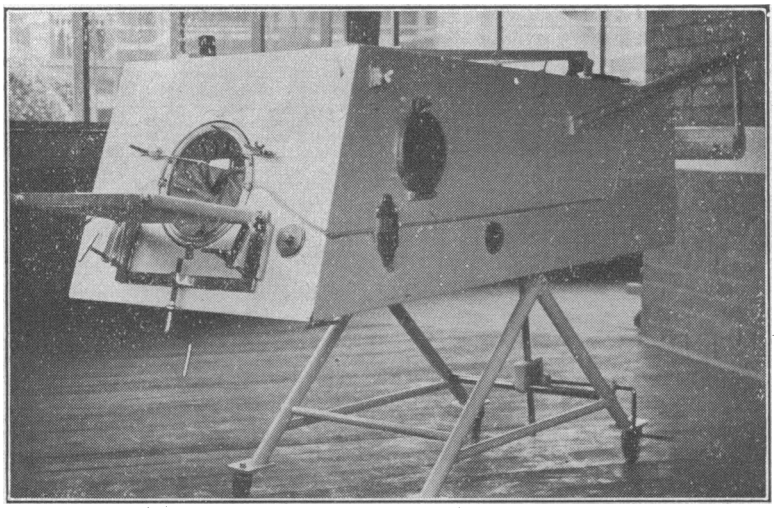

FIG. 4.—Photograph of a "bivalve," or "alligator-type," tank respirator manufactured by Both Equipment Ltd., showing the removable diaphragm collar with a tracheotomy bar in place.

5. With tank respirators of modern bivalve design, using diaphragm collars, nursing and postural drainage are facilitated and in many respects are simpler than with bed nursing (see Fig. 4). A patient with a tracheotomy can be easily managed by the application of a tracheotomy bar to depress the rubber diaphragm neckpiece.

6. In addition, tank respiration provides greater economy of staff, particularly medical staff, when more than one patient is being managed.

The changes in technique and equipment appear to have been successful in reducing the occurrence of pulmonary complications, and comparison of the results seems to show an improvement in prognosis.

The rocking bed has been used with increasing frequency in conjunction with the tank respirator in the early stages of management of selected patients. It is proposed to combine these devices to extend to zones of functioning pulmonary tissue in these patients.

It is apparent from examination of the records of pressure changes within the tank that further refinement of these is desirable.

The results of management have been confined to cases of poliomyelitis for the purpose of comparison with other units. It is considered that the difficulties of management in adults with respiratory failure as the result of poliomyelitis are probably greater than those in infective polyneuritis.

Some of the major difficulties of management, particularly in polyneuritis, arise from the late recognition of respiratory weakness.

It has been found that the application of these principles is successful in the management of severe tetanus in which clonic spasms have demanded total relaxation by means of curare.

Although technical improvements have been of great assistance, success and further improvement in management depend to a large extent on the centralization of these cases so that a full-time staff is able to acquire and maintain specialized experience by constantly managing new cases.

## Summary

The basic considerations leading to three main changes in technique of tank artificial respiration in recent years at Fairfield Hospital are discussed. These involve the use of higher respiratory volumes than usually described; the addition of an automatically actuated valve to the bellows to provide a rapid flow of tracheal air in expiration routinely, and by which a cough may be simulated intermittently; and the application of a larger intratank positive pressure phase so that the patient's chest and abdomen are compressed at each expiration.

The principles of management and the results of the treatment of acute respiratory failure in poliomyelitis at Fairfield Hospital in recent years are described.

The advantages of tank respiration as the method of choice in the respiratory centre over intratracheal positive-pressure methods are given.

I wish to acknowledge the assistance received from Dr. H. McLorinan, who started the Artificial Respiration Unit in 1937 and who has supervised its development since that time. Mr. J. Noble, of Fairfield Hospital staff, and Mr. F. Selby, consulting and manufacturing engineer, have been mainly responsible for the design and construction of the bellows illustrated here, in conjunction recently with Mr. G. Edson, of the respirator workshop at Fairfield Hospital. I also acknowledge the essential part played by other members of the

staff, particularly those of the nursing staff, whose specialized experience has been essential in the management of these patients. Thanks are due to Both Equipment Ltd. for the manufacture of a "bivalve," or "alligator-type," tank respirator, which provides for ease in nursing and general management and also to Dr. P. Colville and the physiotherapists of the Victorian Health Department who have undertaken the respiratory re-education of these patients in the convalescent phase.

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# BACTERIAL CONTENT OF SMALL INTESTINE OF CHILDREN IN HEALTH, IN COELIAC DISEASE, AND IN FIBROCYSTIC DISEASE OF PANCREAS

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Previous workers (Cregan and Hayward, 1953) have shown that when the adult human intestinal tract is healthy the small intestine does not contain a resident flora, any organisms found there being so few in number that they must be regarded as transient contaminants passing through with the ingesta.

It is thought that in certain disease states the small intestine may be colonized by bacteria of a faecal type. Frazer (1949a) suggested that in the sprue syndrome, including coeliac disease, intestinal bacteria normally confined to the lower intestine invade the upper small intestine in large numbers, and that this may result in competition between bacteria and the host for common essential nutrients, particularly B-complex vitamins. The presence of this abnormal small-bowel flora has been repeatedly referred to as a factor in the development of malabsorption and vitamin deficiencies in coeliac disease and adult idiopathic steatorrhoea (Frazer, 1949b, 1952; Frazer *et al.*, 1949). The published literature contains no adequate proof of the existence of this abnormal flora.

The present study was undertaken to determine the extent and nature of the bacterial flora of the small intestine in children with coeliac disease and with steatorrhoea from other causes, as compared with a group of children of similar age distribution but with no gastro-intestinal symptoms at the time of the examination.

## Material and Methods

Four groups of patients were studied, two acting as control groups.

Group 1 consisted of seven patients who had been admitted for elective abdominal surgical operations such as laparotomy, operations for renal anomalies, or interval appendicectomy. These patients had no gastro-intestinal symptoms at the time of operation. Specimens were obtained by injecting 2 ml. of sterile Ringer's solution into the lumen of the small intestine at several levels and then withdrawing some of this. The technique followed was exactly that described by Cregan and Hayward (1953). This group of children was chosen to parallel these workers' findings in "normal adults."

Group 2 consisted of 12 children with no gastro-intestinal symptoms at the time of investigation. Nine of these showed a fat absorption of over 90% as determined by fat balance. In the remaining three fat balance was not carried out, but the stools were normal both macroscopically and microscopically. Specimens were taken from different levels of the bowel by intubation. These patients acted as a control group to compare intubation results with those obtained by direct needling, and also to compare intubation results from "normal" children with those from children with steatorrhoea.

Group 3 consisted of 15 consecutive patients with coeliac disease. The diagnosis was well established from the clinical history and examination, the demonstration of steatorrhoea by fat balance, the presence of normal pancreatic enzymes, and the subsequent response to treatment with a diet free of wheat gluten. Specimens were obtained by intubation, and all patients were examined at a time when they showed steatorrhoea.

Group 4 consisted of seven patients with fibrocystic disease of the pancreas. The diagnosis was well established again from the history and examination and the laboratory data. Pancreatic enzymes were absent, and all the patients showed gross steatorrhoea. Specimens were taken by intubation.

### Collection of Specimens

A tube with a double lumen was used for the intubation. This was constructed by passing a length of fine "polythene" tubing down the inside of a Levin radio-opaque rubber duodenal tube. The polythene was brought out at the tip of the rubber tube. A thin rubber balloon was tied over the tip so that the balloon communicated only with the polythene. The upper end of the polythene was brought out through the side of the rubber tube, and the balloon inflated by attaching a needle and syringe to the end of the polythene. Specimens were aspirated by attaching a syringe to the end of the rubber tube. This tube was used in preference to a Miller–Abbott tube, as it could be passed through the nose in small children and readily visualized under the screen. The tube was sterilized by soaking for 12 to 18 hours in a solution of biniodide of mercury 1/1,000, or by exposure for 24 hours to formalin vapour.

The patient was intubated in the morning after an eight-hour fasting period. A specimen from the stomach was aspirated and the tube was then manœuvred into the duodenum with the aid of fluoroscopy. A duodenal specimen was aspirated, part of this being taken for the estimation of pancreatic enzymes. The balloon was inflated and the child allowed to take fluids, milk, and soft food. This stage was usually reached about mid-morning. The child was screened again about mid-afternoon to ascertain whether the tube had travelled into the jejunum. If so, a further specimen was aspirated. The position of the end of the tube in the bowel could not be precisely determined, but in all cases it was considered to be probably in the lower jejunum. All jejunal specimens were aspirated within eight hours of passing the tube, and some were obtained within four hours. In all cases before the specimen for bacteriological examination was aspirated the tube was washed through with sterile saline and the first few millilitres withdrawn were discarded. This was done to ensure that the specimen examined was from the bowel lumen and not composed of fluid trapped within the tube. A sterile syringe was used for each aspiration.

Saliva specimens were taken with a sterile syringe before intubation was begun.